

HUMAN HEALTH

By Barrett Rock, Lynne Carter, Ben Sherman, Steve Hale, and Paul Epstein



Introduction

Climate change could impact human health in several ways. The effect could be direct, such as heat stroke, or by impacting the geographic range of diseases and vectors (carriers, such as ticks, that transmit disease from one host to another), or indirect, through increased air pollution and decreased water quality. In the New England region, climate impacts (both present and future) to human health fall into three major categories: 1) vector-borne diseases, 2) water/marine-related diseases, and 3) air pollution-related diseases. In addition to these, regional health-related issues include heat stroke and extreme events such as fires, flashfloods, and ice storms.

Health risks associated with climate change are difficult to assess with certainty. Present and future health risks are complicated by such factors as poverty, quality and availability of healthcare, food quality and abundance, sanitation, water quantity and quality, public health infrastructure, access to air conditioners, genetics, and lifestyle choices. In addition to the difficulty of ascribing health conditions to climate change impacts, such impacts on human health vary among different populations and locales. Urban locations are more likely to be impacted by high temperatures, while more rural locations may be more susceptible to vector-borne diseases such as Lyme disease. At present, only limited data and analyses are available at the regional level that connect climate change with human health problems.

At present, climate in the region has significant impacts on human health such as seasonal allergies, winter colds and flu, and summertime air quality problems. Although some health benefits may be seen, regional concerns about the future include increased air pollution, reduced water quality, new distributions of infectious diseases and disease carriers, red tides, heat waves, storms and droughts.

Features of the region make inhabitants and visitors vulnerable to climate-related health changes. High elevation sites favored by hikers increase their exposure to poor air quality. Large deer and mice populations in areas populated or visited by humans increase the likelihood of exposure to ticks infected with Lyme disease. Downwind location and the number of large urban areas and transportation corridors make the region vulnerable to airborne pollution.

Two illustrative case studies dealing with hiker health and Lyme disease are presented at the end of this chapter. These case studies provide valuable insight regarding the present gaps in data and our understanding of climate impacts on human health.

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Current Stresses on Human Health

Infectious and Vector-borne Diseases

Infectious and vector-borne diseases (e.g. the encephalitis viruses and their mosquito vectors) are extremely sensitive to climate conditions – especially temperature and humidity. Their geographic distribution responds actively to changes in minimum winter time temperatures, which have increased in parts of the region from 2-3° F over much of the region during the past century.

Mild, wet winters combined with warm, wet summers punctuated by heavy rains, stimulate mosquito breeding and biting. Northerly outbreaks of mosquitoes have occurred in particularly warm years when there have been several days of above 85° F temperatures. One strain of encephalitis – St. Louis encephalitis – has occurred after excessive rainfall in January and February followed by drought in July. Of particular regional concern is the recent increase in the incidence of eastern equine encephalomyelitis, which can infect humans and horses.

Climate change also could affect the spread of tick-borne Lyme disease, as tick populations survive mild, wet winters and flourish during summer months. According to the Centers for Disease Control, the New England region accounts for 90% of the 100,000+ cases of Lyme disease reported nationwide since 1982. As will be seen in the Lyme Disease Case Study, a more thorough understanding of the impact of climate on ticks is needed.

Air Pollution Impacts on Human Health

Connecting air pollution effects to human health issues is problematic because health risks are complicated by multiple factors. The elderly, the weak, those who smoke, and access to air conditioning, are all factors that influence the impact of poor air quality on human health. As seen in the Hiker Health Case Study in this chapter, sensitive individuals are at greater risk than less sensitive. Where one lives also affects the likelihood of exposure to either chronic or acute poor air quality. In the New England region, those living in major urban centers or along the coast are more likely to be exposed to unhealthy levels of ozone. Those living or recreating at elevations above 2,500-3,000 ft. are also more likely to be exposed to elevated levels of ozone. As the Case Study demonstrates, sensitive individuals are affected even at relatively low levels (40ppb) of ozone.

At present, limited data are available on the impact of ambient air pollution on human health. The Hiker Health Case Study presented is one of the few published studies connecting lung function to exposure of fine particulates and ozone. Although a great deal of data are available, more effort is needed that connects seasonal air quality with documented cases of asthma, chronic emphysema, and other pulmonary problems. Additional work is also needed connecting other forms of air pollution (SO₂, sulfate aerosols, acidic fogs, etc.) with human health problems.

The ice storm impacts included 17 deaths across New York and New England ...

Red Tides

The present warming trend has led to another growing health problem in the region is the incidence of red tides, fish kills, and bacterial contamination in shellfish. Hotter summers favor more toxic forms of algal blooms, such as blue-green algae and the dinoflagellates that often are the cause of red tides. Persistent red tides often reduce oxygen levels in the water, affecting fish populations, sea grasses and shellfish beds. The toxic algae are also taken up by shellfish and cause human health problems when the shellfish are eaten. Other water-borne diseases that may affect the region could include cholera, which can exist both in the dormant and infectious forms, depending on pH, temperature, salinity, and nutrient levels in the water. Food-borne diseases, such as E. coli, salmonella, cyclospora, and hepatitis A, are also enhanced by recent warmer, moister conditions across the New England region.



Extreme Events

In January of 1998, a series of devastating ice storms hit northern New York and New England, causing extensive damage to forests, energy and transportation infrastructure, as well as impacting human health. Over 1.5 million people across the region were without power for up to three weeks, resulting in inconvenience and frustration for many, a dramatic increase in colds and flu-like ailments for some, and carbon monoxide poisoning and deaths from asphyxiation for a few as the result of improper ventilation of power generators.

The ice storm impacts included 17 deaths across New York and New England, many due to carbon monoxide poisoning and asphyxiation. In Canada, 26 deaths were reported, many due to hypothermia. Human health and safety impacts related to the storm were significant, but certainly would have been greater were it not for the rapid response from volunteers, state and local governments, the National Guard, and others.

Other climate-related stresses on human health include the danger presented by extreme events such as floods, hurricanes, droughts, and heat waves. Each of these extreme events can pose direct and indirect health-related risks to vulnerable populations. In addition to drowning deaths, flooding can also be an indirect risk to humans, providing new breeding sites for mosquitoes, or altering water quality.

Droughts also wreak havoc on living systems. They concentrate microorganisms, reducing water quality; they encourage aphids, locusts, and white flies; and, when interrupted by sudden rains, spur explosions of rodent populations that can, among other things, transmit hantavirus pulmonary syndrome. Although incidence of hantavirus is often associated with the Southwest, this disease also has surfaced in the region, particularly in New York. While these examples of extreme events illustrate climate impacts to human health, further analysis is needed before a positive link can be made between these events and the current warming trend.

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Future Impacts of Climate Change on Human Health

Potential Benefits

Many regional inhabitants would welcome milder winters and longer springs and falls. Milder winters could mean a significant reduction in seasonal colds and cases of the flu. Certainly storm-related accidents could be reduced (assuming that ice storm frequency did not increase) and longer growing seasons (including longer springs and falls) would allow more healthful outdoor activities. Such increased outdoor activities could be adversely impacted by extended periods of poor air quality, increases in insect pests due to milder winters, and more outbreaks of infectious and vector-borne diseases. As with the other sectors, the benefits are likely to be outweighed by the negative impacts of climate change.

Infectious and Vector-borne Diseases

The projected increases in temperature and precipitation in the future could promote the further expansion of current infectious and vector-borne diseases. Milder, wetter winters, combined with warmer, wetter summers, especially if punctuated by extreme rain events, could result in more frequent and more northerly outbreaks across the region. In the case of Lyme disease, deer and mouse population dynamics play an important role in disease occurrence and distribution. Since ticks are sensitive to high temperatures, more southerly portions of the region may see a decline over present levels of outbreaks. Since “surprise” occurrences in infectious and vector-borne diseases by definition cannot be predicted, no projections can be made.

Extreme Events

Events such as the 1998 ice storms and other extreme events may be on the increase in the 1990s (see Chapter 2). However, uncertainties exist in projecting further increases in the future. Assuming droughts and flooding were to occur in association with the projected future climate changes, alteration of water quality could impact human health.

Heat-related Mortality

While heat and cold are not presently significant causes of death in the region, cities of the region could experience an increase in heat-related mortality due to climate warming. Three important factors play a role in reaching heat-related mortality thresholds: the effect of absolute temperature (highs); consecutive numbers of hot days; and humidity levels. The threshold effect occurs when a stress, for example temperature or duration of hot days and nights, goes beyond the level after which mortality rises rapidly. During heat waves, there is less nighttime relief from heat stress.

The high humidity levels typical of the region are related to the heavy forest cover combined with frequent rainfall. The evapotranspiration from the dense forest cover maintains and elevates high relative humidity levels. Increasing nighttime temperatures – a rise in minimum temperatures – are likely to be directly detrimental to human health.

The human health sector may be more sensitive to climate change than the other sectors considered in this regional report

Air Pollution Impacts

Projected temperature increases for summer months from both models will mean that air pollution (O₂, SO₂, sulfate aerosols) across the New England Region is likely to become worse. Unless the Nation adopts an active effort to lower NO_x and SO_x emissions in the future, air quality across the region will continue to be a significant human health problem over the next 100 years.

Information and Data Needs

The human health sector may be more sensitive to climate change than the other sectors considered in this regional report because many disease and vectors are climate dependent. However, little effort to date has been made within the human health community to correlate human health issues and climate variables such as air quality across the region, in large part due to the difficulties cited earlier. Another reason may relate to the community's short-term focus on treating the immediate needs of a patient rather than addressing long-term cause and effect relationships. The two most significant gaps in information relate to the need for a more thorough analysis of climate-related impacts on human health and the need for effective education efforts alerting the public to the health hazards and risks associated with such climate-related impacts. An active effort is needed to promote analysis of existing data that may improve our understanding of how climate and human health are interrelated.

Adaptive Strategies

Strategies to address potential impacts of climate change on the health of those residing in and traveling throughout the region are varied in focus and in cost. Some options, listed below, relate generally to health impacts that are felt today as well as in the future, whether they are vector-borne, heat-related, or the result of extreme events. This list is not exhaustive and should be viewed only as a starting point.

- Develop monitoring and response programs to identify and detect emerging diseases and sites of potential vectors, as well as train physicians and public health workers to recognize and treat emerging diseases;
- Educate both physicians and the public on the potential risks to human health posed by climate change;
- Develop early warning systems and preventive programs for populations at-risk from extreme events, vector-borne diseases, and other potentially health-threatening events;
- Support research to investigate methods to curb the proliferation of problem species, including techniques designed to control vector populations; and
- Encourage fortification of sanitation infrastructures to withstand extreme events such as flooding.

CASE STUDY 1

Hiker Health: The Effects of O₃ and Other Pollutants on Pulmonary Function

by Barrett Rock

Mount Washington and the major peaks region in the White Mountains National Forest, NH, host some 60,000 hikers per year. During hot summer days this region is often impacted by elevated levels of ground-level ozone, suspended fine particles of soot, and acidic aerosols (droplets) of anthropogenic origin. The exposure to ozone, fine particulates and strong acidic aerosols pose a health threat to hikers.

One of the few studies of the impact of air quality, under ambient conditions was conducted on hikers engaged in day hikes on Mount Washington. This study of adult hikers was conducted during the summers of 1991 and 1992 by research scientists from the Harvard Medical School, the Harvard School of Public Health, and the Appalachian Mountain Club (AMC). The study evaluated the short term effects of exposure to ambient ozone levels, fine particulate matter (PM_{2.5}) and aerosol acidity, on lung function of healthy adults exposed while hiking at elevation.

Background

Mount Washington and all of the New England Region is downwind from major sources of air pollutants. Tropospheric ozone is the photochemical product of reactions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight and high temperatures. Due to Mount Washington's geographic location, it is subjected to frequent episodic ozone exceedances (both 1-hour 120 ppb and 8-hour 80 ppb) during warm summer months. The summer of 1991 was characterized by a greater number of hot days (at or above 90°F) than was 1992. Due to the connection between temperature/amount of sunlight and ozone formation, higher ozone levels characterized the summer of 1991 than the summer of 1992.

The AMC and the Mount Washington Observatory have been monitoring ozone levels along an elevational gradient (at the base of Mount Washington - elev. 1500 ft./480 m, and at the summit at 6288 ft./1910 m) since 1987. Average ozone exposures during the period of this study ranged from 21 to 74ppb.

Ozone concentrations on a given date may vary considerably with elevation. The base layer of the atmosphere (the troposphere – extending from ground level to 10-15km/6-9 miles above the Earth) is in contact with the surface, resulting in mixing. Because of this, the lowermost layer of the troposphere is called the mixing layer (figure 7.1). The mixing layer extends up to 1km (3,280') or more above the surface, and varies in thickness based on time of day. The tropospheric layer above the mixing layer is termed the “stable layer” (due to the limited amount of turbulence characterizing this layer), and extends to the top of the troposphere. Long-distance transport of air pollutants may occur at the boundary between the mixing and the stable layers, and thus, hiking above approximately 3000' may expose the hiker to elevated levels of ozone and other pollutants not encountered at lower elevations (figure 7.2).

The Study

The lung function of adult hikers was measured before and after hiking on Mount Washington during 74 days during the summers of 1991 and 1992. The mean hourly ozone levels at both base and summit stations during the time of day of most day hikes was at or slightly above 40ppb (Figure 7.2).

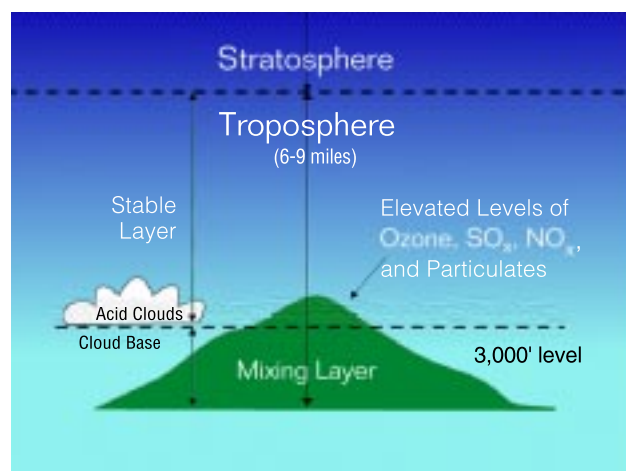


FIGURE 7.1 A diagrammatic representation of the mixing layer at the base of the troposphere, and the affect that elevation has on exposure to both acid cloud moisture and air pollutants.

These results are surprising, especially since average ozone exposure levels were relatively low...

The effects of acute ozone exposure in humans are associated with decreased pulmonary (lung) function and can result in shortness of breath, coughing, and pain while inhaling. Controlled exposure studies associate ozone-exposure (80 - 400 ppb) to acute reduction in lung function and increased respiratory symptoms. Such chamber studies are often inconsistent when compared to natural settings and ambient ozone levels.

The Study Population

Volunteers were solicited from adult hikers (between 18 and 65) beginning a day hike at the trail entrance to AMC trails on the eastern slope of Mount Washington. During the summer months of 1991 and 1992, all hikers who volunteered were evaluated (n=766). Current non-smokers were evaluated in the final study (n=530), along with hikers with self-reported history of physician-diagnosed asthma or severe wheeze symptoms (n=40), and former smokers (n=125).

The Findings

Post-Hike percentage of change was determined and adjusted for hiker age, sex, smoking status (former vs. never), health history (asthma or wheeze), hours hiked, carrying a backpack, reaching the summit, and ambient temperature. It was found that for Every 50 ppb increment

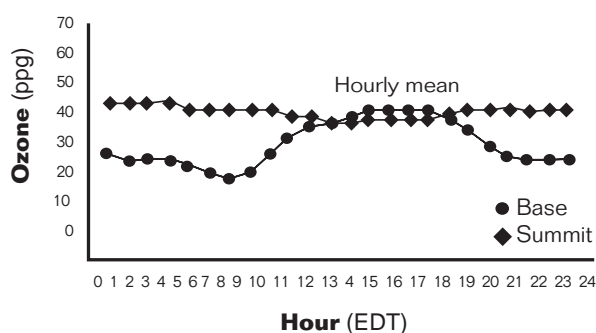


FIGURE 7.2 Mean hourly ozone levels (ppb) at the summit and base of Mt. Washington for the 74 days on which hikers were evaluated in summer 1991 and 1992. Note the pattern of the base station hourly mean ozone levels (elevated in the afternoons) and the lack of such a pattern at the summit .

in mean ambient O_3 there was a 2.6% decline in forced expiratory volume (FEV_1); 2.2% decline in forced vital capacity (FVC), and a 4-fold greater response (15% reduction) in hikers with a history of asthma or wheeze. Former smokers exhibited increased sensitivity to a lesser degree than those with a history of asthma or wheeze.

The results presented in this hiker health study indicate that the effects of ozone exposure were greater than have been described previously in either field studies or controlled exposure chamber studies. These results are surprising, especially since average ozone exposure levels were relatively low (approximately 40ppb), one third of the current EPA ambient air quality standard (1-hour exposure to 120ppb ozone). These findings suggest that chronic exposure (8-hours duration) to low levels of ozone may be as damaging to pulmonary function as acute (short-term) exposure to higher levels of ozone. Finally, these results raise the concern that supposedly healthful exercise in the great outdoors may actually be hazardous to our health.

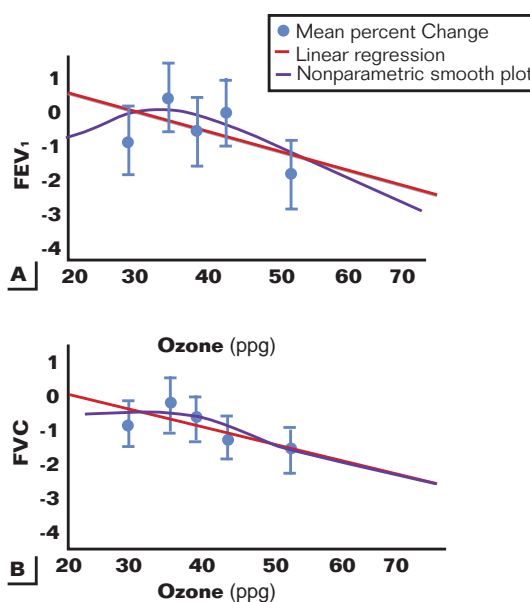


FIGURE 7.3 Posthike percentage changes in (A) forced expiratory volume in 1 sec (FEV_1) and (B) forced vital capacity (FVC) versus mean O_3 exposure after adjustment for age and other factors.

CASE STUDY 2 Lyme Disease

by Barrett Rock

One of the most important vector-borne diseases for the region is Lyme disease, borne by deer ticks. Warmer, wetter winters, coupled with more moisture year-round may promote the breeding and abundance of these vectors, their biting rates and growth of the microorganisms involved. Thus, the types of the climate change projected by the Hadley (increases of 6°F and 30% increase in precipitation) and Canadian (increases of 10°F, 10% increase in precipitation) climate models over the next 100 years are likely to have significant impacts on the occurrence and distribution of Lyme disease.

Most important for biology, and in particular, diseases, is the minimum temperature (both nighttime and wintertime). Over the past century, a regional increase of 1.8°F in winter temperatures has occurred. Minimum temperatures are increasing at over twice the rate of the regional average annual temperature, and may account for the extension of Lyme disease across the region.

Background

Infectious and vector-borne diseases are known to be extremely sensitive to climate conditions, and their geographic distribution responds directly to changes in minimum wintertime temperatures. Research has documented a direct spatial and temporal relationship between deer tick

nymphal abundance and human Lyme disease, as well as a strong correlation between the spread of Lyme disease and precipitation/soil moisture. Thus, the deer ticks and the Lyme disease virus that they carry may be highly responsive to temperature and humidity. Figure 7.4 presents the distribution of reported cases of Lyme disease in 1998, and figure 7.5 presents the “danger months” when the likelihood of coming in contact with deer ticks is the highest.

The milder wet winters, combined with warmer wet summers projected by the Hadley model could characterize the New England region in the next century, could result in more frequent and more northerly outbreaks of Lyme disease throughout the region. At present, the highest number of cases reported in the United States for Lyme disease in humans centers on the Northeast, where the highest number of cases reported for 1998 were in New York and Connecticut (Figure 7.4). However, climate change could provide a health benefit to humans vulnerable to tick-borne diseases. Ticks are sensitive to high temperatures, and the summer temperature increase projected in the Canadian model could result in tick populations declining with this more extreme warming trend, especially in southern and coastal portions of the region.

Uncertainties

Deer tick population dynamics may also be influenced by the production of acorn crops (mast) across the region. Both deer and white-footed mice use acorns as a major food source and

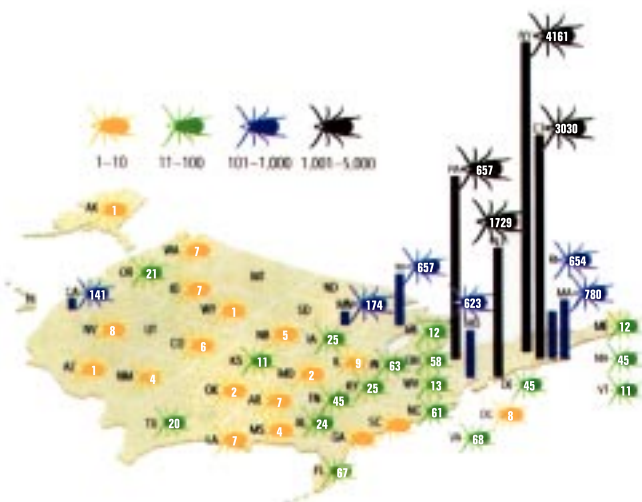


FIGURE 7.4 Reported cases of Lyme disease in 1998.

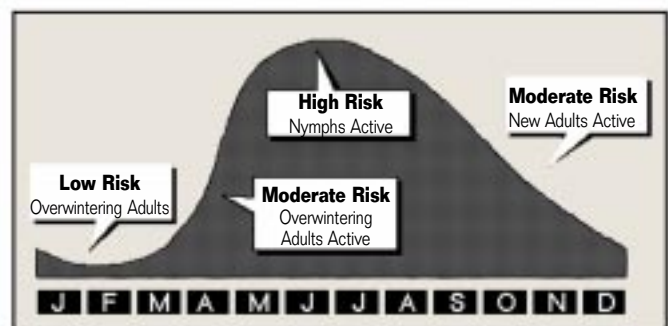


FIGURE 7.5 Lyme Disease: The Danger Months.

“At-risk” areas for high tick populations need to be identified and information provided to people living in the area.

winter survival of both species depends both on the severity of the winter and on access to, and extent of, acorn crops.

Although some years are good acorn production years for oak (up to 50,000 acorns produced per mature tree) and others are poor mast years (fewer than 1,000 acorns per tree), the actual connection between climate and acorn production is poorly understood. In Rhode Island, 1994, 1996 and 1998 were wet years and good years for ticks and Lyme disease outbreaks, while 1993, 1995 and 1997 were dry years, bad for ticks, with fewer cases of Lyme disease reported. Dry years are apparently good for mast production, and heavy mast production, coupled with a mild winter, will result in increases in mice and deer populations in the following year and (due to a larger reproducing population) the year following. To better understand the impacts that potential climate change in the future may have on Lyme disease, we must learn more about these various factors and how they influence deer tick population dynamics.

Soil moisture is also important because it allows for the survival of the tick nymphal stage across the summer months. If the soil is drying up by Memorial Day when the nymphal stage ticks are emerging, many of them may not survive, meaning a bad year for ticks, since studies suggest that the nymphal stage is the most important stage in determining the population of ticks.

Lessons Learned

- A better understanding of the key factors affecting Lyme disease transmission (masting vs. soil moisture or both) is needed.
- “At-risk” areas for high tick populations need to be identified and provided to people living in the area.
- Improved educational programs on the factors that influence tick population dynamics, as well as the methods of transmission of the infectious agent, are needed.
- Once the factors affecting Lyme disease transmission are known, “tick alert” announcements should be made public.
- Hotter summers in the future could limit tick populations, since ticks are sensitive to high temperatures.

Adaptive Strategies

To reduce human infections with tick-borne diseases, focus needs to be placed on the areas where the tick concentrations are highest. In these targeted areas, physician education, improved diagnostics, and regionally based community-implemented tick control strategies should be initiated along with effective public education programs. For reducing human exposure to the ticks, one method would be to begin issuing “disease impact statements” made as new land is developed for use.

Currently, 75% of the Lyme disease infections are in people who reside in known at-risk areas. Once the relationship between masting and soil moisture are clarified and characterized, annual public service announcements should be issued to alert the public on the health risks as they vary from year to year.